450

MOLT IN THE NORTHERN FUR SEAL

by Victor B. Scheffer and Ancel M. Johnson

SPECIAL SCIENTIFIC REPORT–FISHERIES No. 450

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

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Washington, D. C.
October 1963

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ABSTRACT

Growth and replacement of the fibers of the back pelage were studied on 706 fur seals *(Callorhinus ursinus)*, of which 321 were in molt. Duration of molt in the individual is about 15 weeks. Extreme duration of the molting season is mid-June to mid-March of the following year. The estimated mid-dates of molt for 1-year males and females are, respectively, 11 September and 26 September; for 10-year males and females, 12 October and 13 November. The mid-date for males is 3.4 days later with each year of age; for females 5.5 days. Fur fibers tend to accumulate in the skin with age. The fur fiber count per bundle rises from 14 to 24 (mean 17.9) in the first pelage to 51 in the adult female and 68 in the adult male. In 120 seals of various ages and both sexes, the mean count of fur fibers per bundle is 39.2. The black birth coat is replaced by the silvery adult-type pelage at about age 3 months. The skin thickens with age and with molt. Sebaceous glands are functional at birth; sweat glands and their surrounding fat cells do not mature until the end of the first year.

Pilosebaceous units (each with a guard hair, a fur bundle, a skin pore, and associated structures) disperse as the seal increases in age and body surface area. The number of units per $cm.^2$ is 1,296 for a 3-year male and 790 for a 15-year female. The unit count on the back is similar to the count on the belly, and the number of fur fibers per bundle is similar on back and belly. In the back pelage of the 12-year female there are estimated to be 275,634 total fibers per $inch^2$.

INTRODUCTION

General information on the pelage of the northern fur seal, *Callorhinus ursinus*, with a glossary of technical terms, was recently published (Scheffer, 1962). Now specific evidence is offered on growth and replacement of the pelage fibers with relation to age, sex, and season. Notes on corollary changes in the skin are included. The main purpose of the study is to provide information on molt so that pelts can be harvested by the Government at the time when molt is not in progress, that is, when the pelts are of greatest commercial value.

MATERIALS AND METHODS

The study is based on pelage samples from 706 seals, of which 321 were in molt at the time of collection (table 1). They were taken in all months of the year on the Pribilof Islands or in waters off the west coast of North America, 1958-61.

Specimens Used for Identifying Molt Stage

From each seal, the field collector cut a strip of skin about 2 by 4.5 cm. lengthwise of the body from the middle of the back between the fore flippers. He scraped off the fat with a knife, washed the sample free of blood and dirt, and placed it in 25 ml. of 10 percent neutral buffered formalin. Some weeks later, each sample was cut in half to provide material for (a) dry slices, transversely sectioned to show gross relationships of skin and pelage, and (b) paraffin mounts, horizontally sectioned in depth and stained to show histological detail (fig. 1).

Dry slices, transversely sectioned.--Half of the sample was removed from formalin and dried at room temperature under light pressure. From it, thin slices parallel to the lay of the roots were cut in a plane midway between frontal and horizontal. Measurements made later on the sections are referred to as "slant depth." Slant depth is 142 percent of vertical depth. Each slice is about 2/3 mm. thick and 10 mm. wide. On a typical slice about 100 pilosebaceous units can be seen. A unit includes a guard hair, a bundle of underfur fibers, a skin pore (pilary funnel), a sebaceous gland-complex, a sweat gland, and associated minor structures. The slices were degreased in methyl chloroform.

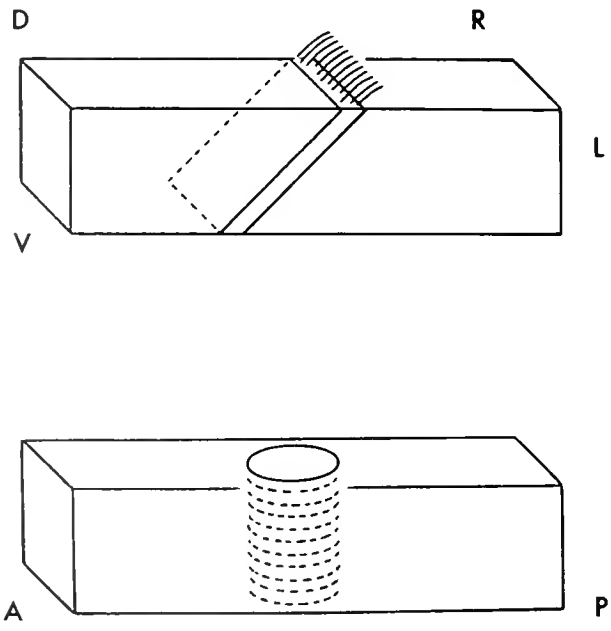

Figure 1.--Orientation of pelage samples, diagrammatic; body represented as lying on its belly with its head at viewer's left. D - V = dorsal to ventral axis; R - L = right to left axis; A - P = anterior to posterior axis. (Above) dry slice, transverse. (Below) ten paraffin mounts, horizontal.

Later, one slice was selected and permanently mounted, anterodorsal side upward, on a glass slide under a clear plastic cover slip (fig. 2). Other slices were temporarily mounted in various media. The refractive index (RI) of the keratin of hair is about 1.548. Experimentally, in order to see and to photograph structural details, dry slices were mounted in a number of liquids. *Isopropanol* (RI 1.378) has proved to be the best nonclearing mountant for rapid examination of dry slices. In it, all surface structures, including pelage fibers and exposed roots, stand out clearly. *Cedarwood oil* (RI 1.513) is the most useful clearing agent. It clears moderately well and it clears progressively, so that certain structures (e.g., sebaceous glands) tend to remain opaque for a few minutes after others have cleared. It evaporates rather slowly. It has the disadvantage of trapping fine air bubbles which, however, disappear in a day or two. It enables one to see pigment granules and refringent root sheaths. *Ortho-nitrotoluene* (RI 1.547) clears more thoroughly; its refractive index is near that of keratin. However, it evaporates quickly, has an offensive odor, and is toxic.

Paraffin mounts, horizontally sectioned.--The other half of the original specimen was prepared as a series of horizontal sections in a synthetic medium with a refractive index of 1.528. Each section is 15 microns thick, stained with hematoxylin and eosin, representing levels from the surface, with lumens of the pilary funnels, to the deepest parts of the sweat glands and hair roots.

Table 1.--Number of pelage specimens of the northern fur seal by age, sex, and month

Age	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Years							*Male*						
0[1]	--	--	--	--	--	--	--	--	6	2	--	--	8
0[2]	--	--	--	--	--	--	--	--	4	3	3	--	10
1	--	1	2	4	--	1	1	--	6	4	1	--	20
2	1	1	3	7	1	7	11	3	13	3	12	--	62
3	1	1	3	8	1	11	7	8	5	4	6	--	55
4	1	--	--	5	--	4	3	3	6	4	1	--	27
5	--	--	--	--	--	6	1	--	6	3	--	--	16
>5	--	--	--	1	4	12	4	3	8	3	2	--	37
Total males	3	3	8	25	6	41	27	17	54	26	25	--	235
							Female						
0[1]	--	--	--	--	--	--	1	--	6	1	--	--	8
0[2]	--	--	--	--	--	--	--	--	1	5	3	--	9
1	2	--	10	3	2	--	1	--	--	3	--	--	21
2	3	--	6	4	1	--	--	1	13	4	3	--	35
3	14	15	12	5	1	2	3	6	12	5	3	--	78
4	7	15	11	13	1	3	5	9	7	5	2	1	79
5	3	7	4	2	--	4	10	5	8	4	2	--	49
>5	21	24	27	26	15	14	11	11	30	7	4	2	192
Total females	50	61	70	53	20	23	31	32	77	34	17	3	471
Total both sexes	53	64	78	78	26	64	58	49	131	60	42	3	706

[1] black pup.
[2] silver pup.

Figure 2.--Example of a "dry slice, transverse," mounted on a 25 x 75 mm. slide; anterodorsal view; pelage in early molt.

Specimens Used for Estimating Abundance of Fibers

Using a special technique, skin samples of measured area were collected from 21 seals for the purpose of estimating abundance of pelage fibers per unit area of body surface. (1) On the back and belly of the freshly killed seal, the four corners of a 10-cm. square were marked by injecting a few drops of black waterproof ink through the pelage into the dermis. (2) A square of skin-with-pelage including the four black spots was removed by knife and pinned flesh-side up on a slab of wax, stretched slightly in order to restore the dimensions as in life; then fixed in formalin. (3) Later, a patch was sheared from the pelage and circular plugs of skin were removed, each 0.4 cm.^{2} in area. A trephine for removing such plugs has been described by Carter and Clarke (1957). (4) Each plug was soaked with alcohol and dried between flat surfaces. Its epidermal side was photographed. From photoenlargements at 15 X, pilosebaceous units per 0.4 cm.^{2} were counted. (5) From other plugs in formalin, paraffin mounts were prepared and individual fur fibers per bundle were counted under a microscope.

Age of Individual Specimens

The study was designed to show the molt characteristics of each year class to, and including, the fifth, and of pooled classes above the fifth.

The ages of many individual seals collected during the study are exactly known from numbered tags which had been applied in the first summer of life. The ages of others have been estimated from annular layers on the upper canine teeth. For certain individuals where the tooth layers are obscure, or where the field record shows simply "adult," or "old," or "10 +," an arbitrary age of 10 years has been assigned to males and 12 years to females. These individuals include 2 (or 1.4 percent) of 148 males in molt and 17 (or 8.9 percent) of 192 females in molt.

Measurements

In order to visualize and to describe the procession of molt it was necessary at first to take 11 measurements on each specimen. Later, when diagnostic features of each stage of molt were known, only six key measurements were taken. The list follows:

1. Color of underfur.--Munsell color of the underfur on a dry mount lying ventroposterior

side upward on a table, cut edge toward the observer; light from two 15-watt "daylight" fluorescent lamps coming toward the specimen at an angle of 45°, and toward the observer (Munsell Color Company, 1954; National Bureau of Standards, 1955).

2. Maximum depth of underfur.--On a dry mount, slant depth from epidermis to surface of the underfur layer, all fibers in natural, slightly bent, or wavy attitude.

3. Percent guard hairs of previous generation.--A rough estimate of hairs more than 1 year old, from the evidence of worn tips and faded blades; at magnification of 30 X.

4. Depth of skin.--Slant depth of the dried dermis-plus-epidermis.

5-6. Percent mature and immature guard hairs; percent mature and immature underfur fibers.--Estimated on the basis of 100 guard hair follicles and 20 underfur follicular bundles on a paraffin mount, horizontal, near the surface.

STAGES OF MOLT

Early in the present study the important stages of molt were identified and defined. Molt was analyzed primarily on the basis of changes in the guard hair, since changes in the underfur are difficult to follow. Once a new fur fiber has erupted, it becomes invisible among 250 to 350 other fibers per mm.^{2}. The stages of molt, and the duration of each, are:

Resting Stage

About 37 weeks; hair roots dormant. The skin is white; the follicles are resting; the hair roots are club-shaped, nearly colorless, and without bulb. All fibers are mature. Near the start of the resting stage in early winter the outer guard hairs are dark and sharp-tipped; near the end in late summer they are faded and blunt or frayed. For an indefinite period in the early resting stage the skin is said to be "prime."

Beginning Molt

About 2 weeks; roots becoming active. All evidence of molt is subsurface; at first not visible to the naked eye. The first underfur bulbs are forming and are producing fiber which are shooting toward the surface. Fe to many guard hair bulbs are forming.

Early Molt

About 6 weeks; new hairs erupting. Ne guard hair tips are sprouting into the underfu layer. Others are beneath the surface of th skin, and still others have reached the oute surface of the underfur pile. Black streakir in the skin is more prominent than in ar other stage. Up to 35 active guard hair bulk per linear cm. on a transverse section can b seen. Up to 73 percent of the units at the sur face contain twin guard hairs: old and nev Colloquially, this is the "peepy" stage.

Late Molt

About 4 weeks; new hairs maturing. The mai wave of new guard hair tips has reached to c beyond the outer surface of the underfur laye Last year's guard hairs, though worn, are sti the longest hairs in the pelage. Pigment produc tion at the base of the guard hair is declinin Old guard hairs are being shed rapidl Colloquially, this is the "rank" stage.

Ending Molt

About 3 weeks; roots regressing; a transitio between late molt and resting. Molt is n visible to the naked eye. The longest hairs the pelage are those of the new crop, a few which are still growing. Many guard hair roo are finely speckled where the bulb has dis appeared, but diffuse pigment remains.

MOLT IN RELATION TO AGE, SEX, AND SEASON

For each of 671 specimens representir animals older than pups, the stage of molt wa diagnosed as resting, beginning, early, late, c ending (table 2).

Total Duration of the Molting Period

Molting individuals were collected as ear as 21 June and as late as 23 January of th following year. In June, 5 of 64 seals take were in beginning molt. The June-moltir

Table 2.--Stages of molt of the northern fur seal by age, sex, and month (number of specimens in each stage of molt, excluding 35 pups)

Stage of molt	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Age 1												
Male												
Ending	-	-	-	-	-	-	-	-	2	3	-	-
Late	-	-	-	-	-	-	-	-	3	1	-	-
Early	-	-	-	-	-	-	-	-	1	-	-	-
Beginning	-	-	-	-	-	1	-	-	-	-	-	-
Resting[1]	-	1	2	4	-	-	1	-	-	-	1	-
Total	-	1	2	4	-	1	1	-	6	4	1	-
Female												
Ending	-	-	-	-	-	-	-	-	-	2	-	-
Late	-	-	-	-	-	-	-	-	-	-	-	-
Early	-	-	-	-	-	-	-	-	-	-	-	-
Beginning	-	-	-	-	-	-	1	-	-	-	-	-
Resting[1]	2	-	10	3	2	-	-	-	-	1	-	-
Total	2	-	10	3	2	-	1	-	-	3	-	-
Age 2												
Male												
Ending	-	-	-	-	-	-	-	-	-	-	2	-
Late	-	-	-	-	-	-	-	-	7	1	7	-
Early	-	-	-	-	-	-	1	2	6	2	2	-
Beginning	-	-	-	-	-	1	10	1	-	-	-	-
Resting[1]	1	1	3	7	1	6	-	-	-	-	1	-
Total	1	1	3	7	1	7	11	3	13	3	12	-
Female												
Ending	-	-	-	-	-	-	-	-	-	-	1	-
Late	-	-	-	-	-	-	-	-	6	3	1	-
Early	-	-	-	-	-	-	-	1	5	1	1	-
Beginning	-	-	-	-	-	-	-	-	2	-	-	-
Resting	3	-	6	4	1	-	-	-	-	-	-	-
Total	3	-	6	4	1	-	-	1	13	4	3	-
Age 3												
Male												
Ending	-	-	-	-	-	-	-	-	-	-	2	-
Late	-	-	-	-	-	-	-	-	-	4	3	-
Early	-	-	-	-	-	-	-	-	4	-	-	-
Beginning	-	-	-	-	-	1	6	6	1	-	-	-
Resting[1]	1	1	3	8	1	10	1	2	-	-	1	-
Total	1	1	3	8	1	11	7	8	5	4	6	-

See footnotes at end of table.

Table 2.--Stages of molt of the northern fur seal by age, sex, and month (number of specimens in each stage of molt, excluding 35 pups).--Continued

Stage of molt	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Age 3						
						Female						
Ending	-	-	-	-	-	-	-	-	-	-	2	-
Late	-	-	-	-	-	-	-	-	1	-	1	-
Early	-	-	-	-	-	-	-	-	5	4	-	-
Beginning	-	-	-	-	-	1	1	5	6	1	-	-
Resting	14	15	12	5	1	1	2	1	-	-	-	-
Total	14	15	12	5	1	2	3	6	12	5	3	-
						Age 4						
						Male						
Ending	-	-	-	-	-	-	-	-	-	-	-	-
Late	-	-	-	-	-	-	-	-	-	3	-	-
Early	-	-	-	-	-	-	-	-	5	1	-	-
Beginning	-	-	-	-	-	-	3	2	1	-	-	-
Resting[1]	1	-	-	5	-	4	-	1	-	-	1	-
Total	1	-	-	5	-	4	3	3	6	4	1	-
						Female						
Ending	-	-	-	-	-	-	-	-	-	-	-	1
Late	-	-	-	-	-	-	-	-	-	-	2	-
Early	-	-	-	-	-	-	-	-	-	4	-	-
Beginning	-		-	-	-	1	2	7	6	1	-	-
Resting	7	15	11	13	1	2	3	2	1	-	-	-
Total	7	15	11	13	1	3	5	9	7	5	2	1
						Age 5						
						Male						
Ending	-	-	-	-	-	-	-	-	-	1	-	-
Late	-	-	-	-	-	-	-	-	-	1	-	-
Early	-	-	-	-	-	-	-	-	6	1	-	-
Beginning	-	-	-	-	-	-	-	-	-	-	-	-
Resting	-	-	-	-	-	6	1	-	-	-	-	-
Total	-	-	-	-	-	6	1	-	6	3	-	-
						Female						
Ending	-	-	-	-	-	-	-	-	-	-	-	-
Late	-	-	-	-	-	-	-	-	-	1	-	-
Early	-	-	-	-	-	-	1	-	-	3	2	-
Beginning	-	-	-	-	-	-	3	1	6	-	-	-
Resting	3	7	4	2	-	4	6	4	2	-	-	-
Total	3	7	4	2	-	4	10	5	8	4	2	-

See footnotes at the end of table.

Table 2.--Stages of molt of the northern fur seal by age, sex, and month (number of specimens in each stage of molt, excluding 35 pups).--Continued

Stage of molt	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Age over 5[2]						
						Male						
Ending	-	-	-	-	-	-	-	-	-	2	2	-
Late	-	-	-	-	-	-	-	-	-	1	-	-
Early	-	-	-	-	-	-	-	-	-	-	-	-
Beginning	-	-	-	-	-	-	1	3	7	-	-	-
Resting	-	-	-	1	4	12	3	-	1	-	-	-
Total	-	-	-	1	4	12	4	3	8	3	2	-
Mean age	-	-	-	10	9	11	6	10	9	11	8	-
						Female						
Ending	4	-	-	-	-	-	-	-	-	-	-	1
Late	2	-	-	-	-	-	-	-	1	1	1	-
Early	1	-	-	-	-	-	-	1	12	1	-	-
Beginning	1	-	-	-	-	-	-	5	13	4	3	-
Resting[3]	13	24	27	26	15	14	11	5	4	1	-	1
Total	21	24	27	26	15	14	11	11	30	7	4	2
Mean age	12	12	14	10	12	11	8	10	11	9	9	11

[1] "Resting" seals in October and November have passed through the autumnal molt of this year.

[2] Mean age of the seals in each sample is indicated below. Where the age of a male is known only as "adult," "or bull," or "old," age 10 has been arbitrarily assigned. Where the age of a female is known only as "10+," age 12 has been arbitrarily assigned.

[3] A "resting" seal in December has passed through the autumnal molt of this year. The 13 "resting" seals in January are treated statistically as resting, post-molt, each with a code value of 15.

specimens were young ones; none older than 4 years. In January (up to the 23d) 8 of 53 seals taken were still molting. The eight were females at least 10 years of age. Some of them would have continued in molt into February or March. On the other hand, no molting specimens appear among 24 females older than 5 years actually taken during February, nor any among 27 taken during March.

Thus the overall molting period is certainly 8 months, and probably 9. Only in the months of April and May could one be sure of finding all seals in resting pelage.

Duration of Molt in the Individual

The data of the present study have been obtained by killing seals from a large free population. How, then, can one estimate the duration of molt in the individual?

1. The duration of molt in any individual must be less than the duration in a group of which that individual is a member. In a fairly homogenous group--the combined 2- and 3-year-old males for the period July to November--67 seals in a sample of 72 are in molt (table 2). Obviously the average duration of molt in the individual is less than 22 weeks.

2. Among 64 seals collected in June, 5 are just beginning to molt. (The five include 1-, 2-, and 3-year males; 2- and 4-year females.) The mean date of collection is 24 June. Among 49 seals collected in October and 36 in November, 5 have passed through the molt and have returned to resting stage. (The five include 1-, 2-, 3-, and 4- year males and a 1-year female.) The mean date of collection is 11 November. The difference between 24 June and 11 November is 140 days, or 20 weeks.

3. From the report of Bartholomew and Hoel (1953, fig. 1) the peak of the pupping season is mid-July. At birth the silver pelage has already started to form. By the end of September nearly all pups have replaced the black birthcoat with a silvery one. It is reasonable to deduce that by mid-October the pelage of nearly all pups has returned to resting stage, and that 3 months or 13 weeks have elapsed during the growth of the first adult-type coat.

4. Scant evidence on individual molt had been obtained in an earlier study (Scheffer, 1962, p. 27). In the Seattle Zoo, a male and a female silver pup in prime new pelage were partly shorn on 24 November 1952; regrowth of the pelage was observed up to 26 October of the following year. The findings of that experiment are compatible with those of the present study. The old and the new findings have been reviewed and a reconstruction of events in the molt has been prepared (table 3). The evidence points to a duration of about 15 weeks.

The molt of the underfur precedes that of the guard hair. The time difference is certainly days, rather than weeks, and is assigned a value of 1 week (table 3). A more exact value could be obtained by taking biopsy plugs from a captive seal at intervals of a few days.

There is no evidence from study of individuals on duration of molt in older, as against younger, seals. In the next section (page 15) it will be shown that the overall length of the molting period increases with age of seal. This could mean that, in older individuals, either molt is more erratic or its progress is slower, or both.

At this point it will be helpful to compare duration of molt in the seal with that in three other carnivores:

1. In the ferret *Putorius vulgaris*, "the new winter coat is completed within 7 or 8 weeks" (Bissonnette, 1935, p. 166). There is a second molt of unspecified length in the spring.

2. The mink *Mustela vison*, grows a summer coat between mid-April and mid-July; a winter coat between early September and late November (Dolnick, 1959, p. 6). During each molt the duration of growth is 13 weeks.

3. The silver fox *Vulpes fulva*, grows a single coat between late April and late November (Bassett and Llewellyn, 1948, p. 599-601). While the total duration is 7 months, the growth of new fibers on the back alone requires less time. Bassett has estimated (in letter, 1962) that the duration of molt on the back is from 1 August to 10 November, or 101 days (14.5 weeks), with great variation.

Variation in Molt by Age, Sex, and Month

Excluding pups, six age groups of each sex are involved in the present study. An attempt has been made to estimate the mid-date of molt for each group. From the estimates, certain conclusions have been drawn with regard to variation in time of molt by age and sex. In order to prepare the estimates of mid-date, the following steps were taken:

1. For each stage of molt except resting a code number was assigned, representing its distance (progression in weeks) from resting condition (table 3). The code number is, for beginning stage 1, early 6, late 11, and ending 14. In addition, code number 15 was assigned to the "resting post-molt" stage in order to take advantage of 6 specimens observed in this condition in October-December and 13 in January.

2. For each monthly sample by age and sex, a mean code number was calculated. For example, for the yearling male in September (table 2) this is $[(1 \times 6) + (3 \times 11) + (2 \times 14)] \div 6 = 11.2$. The calculated results are given in table 4.

3. For each group (e.g., yearling males) a regression line was plotted on the basis of the monthly mean code numbers. The X-axis for all groups was the same, scaled as June = 1,

Table 3.--Estimated time schedule of individual molt of the northern fur seal

Example date	Lapsed time, weeks	Stage of molt in the underfur	Stage of molt in the guard hair
24 June[1]	0	beginning	. . . .
1 July	1	. . . .	beginning
8 "	2	early	. . . .
15 "	3	. . . .	early
22 "	4	. . . .	. . . .
29 "	5	. . . .	. . . .
5 August	6	. . . .	. . . .
12 "	7	. . . .	. . . .
19 "	8	late	. . . .
26 "	9	. . . .	late
2 September	10	. . . .	. . . .
9 "	11	. . . .	. . . .
16 "	12	ending	. . . .
23 "	13	. . . .	ending
30 "	14	complete	. . . .
7 October	15	. . . .	complete

[1] This is the mean date of beginning molt for five seals observed in molt out of 65 in June.

Table 4.--Stages of molt of the northern fur seal coded as weeks from start[1]

Age	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Years				*Male*				
1	1.0	--	--	11.2	13.3	15.0	--	--
2	0.1	1.5	7.3	7.9	7.7	10.5	--	--
3	0.1	0.9	0.7	5.0	11.0	10.2	--	--
4	--	1.0	0.7	5.2	9.7	15.0	--	--
5	--	--	--	6.0	10.3	--	--	--
>5	--	0.3	1.0	0.9	13.0	14.0	--	--
				Female				
1	--	1.0	--	--	14.3	--	--	--
2	--	--	6.0	7.5	9.7	10.3	--	--
3	0.5	0.3	0.8	3.9	6.2	13.0	--	--
4	0.3	0.4	0.8	0.9	5.0	11.0	14.0	--
5	--	0.9	0.2	0.7	7.3	6.0	--	--
>5	--	--	1.0	3.2	3.0	3.5	14.5	13.3
				Male				
All ages	0.2	1.0	1.9	6.1	10.9	11.1	--	--
				Female				
All ages	0.4	0.7	0.9	3.6	6.7	8.4	14.3	13.3
				Both sexes				
1	1.0	1.0	--	11.2	13.7	15.0	--	--
2	0.1	1.5	7.5	7.7	8.9	10.5	--	--
3	0.2	0.7	0.8	4.2	8.3	11.1	--	--
4	0.3	0.6	0.7	2.8	7.1	12.3	14.0	--
5	--	0.9	0.2	3.1	8.6	6.0	--	--
>5	--	0.3	1.0	2.7	6.0	7.0	14.5	13.3

[1] For 340 specimens a code number was assigned to each stage of molt, as follows: beginning 1, early 6, late 11, ending 14, and resting postmolt 15. On the basis of this code, the monthly mean values from table 2 have been entered in table 4. In the body of the table there is given for each group (by age, sex, and month) the mean status of molt in terms of weeks from start of molt. Mean age for >5 males is calculated as 8.7 years; for >5 females as 10.8 years.

July = 2 . . . January = 8. The Y-axis for all groups was the same, scaled as weeks in molt from 0 to 15. Each line reflected the procession of molt.

4. Where each regression line intersected a horizontal representing code number 7.5 (the midpoint of the 15-week molt), a vertical was dropped to the X-axis, thus establishing a date about which the molt stages for this group tend to cluster. The points or mid-dates are given in table 5.

5. Linear, quadratic, and logarithmic curves were fitted experimentally to the data of table 5 to determine which best might represent the trend in retreating mid-date of molt with increase in age of seal (figs. 3-6). As a growth phenomenon, the relationship between molt and age would be expected to be represented by

Table 5.--Molt mid-dates of the northern fur seal calculated from regression of molt stage on month[1]

Age	Number in sample	Mid-date
Years	*Male*	
1	12	240 (28 Aug.)
2	49	268 (25 Sep.)
3	41	251 (8 Sep.)
4	17	266 (23 Sep.)
5	9	267 (24 Sep.)
8.7	20	282 (9 Oct.)
Total	148	
	Female	
1	4	241 (29 Aug.)
2	21	249 (6 Sep.)
3	31	294 (21 Oct.)
4	32	298 (25 Oct.)
5	29	356 (22 Dec.)
10.8	75	321 (17 Nov.)
Total	192	
	Both Sexes	
1	16	230 (18 Aug.)
2	70	266 (23 Sep.)
3	72	290 (17 Oct.)
4	49	298 (25 Oct.)
5	38	309 (5 Nov.)
10.4	95	301 (28 Oct.)
Total	340	

[1] The mid-date is expressed as the number of calendar days from the first of January. In obtaining mid-dates, the X-axis represented months from June to January; the Y-axis represented weeks in molt from 0 (resting, pre-molt) to 15 (resting, post-molt). See also table 6, where these mid-dates are smoothed.

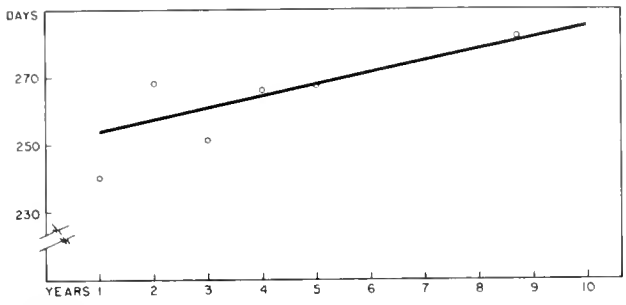

Figure 3.--Molt mid-dates; straight line fitted to data from table 6; male. (Y = 250.55 + 3.43 X.)

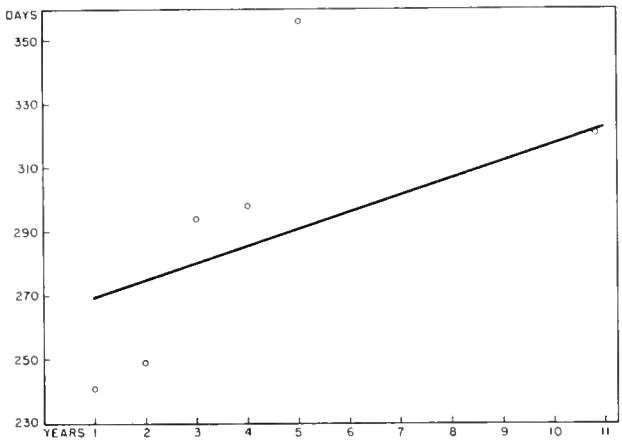

Figure 4.--Molt mid-dates; straight line fitted to data from table 6; female. (Y = 264.05 + 5.46 X.)

a quadratic or logarithmic curve. The present data, however, suggest a linear relationship. Spotty sampling of older animals, especially males in winter, is probably the reason. The mid-dates of molt for some ages have been estimated from both linear and logarithmic equations (table 6). The following conclusions are predicated on a linear relationship:

The sexes have a similar molt pattern. The molt begins about 20 July in yearling males and reaches the mid-date on 11 September. In yearling females it begins about 5 August and reaches the mid-date on 27 September, 16 days later than the mid-date for males. The estimated mid-date for males is 3.4 days later with each year of age; for females, 5.5 days later with each year of age. The rate of change of the mid-date is significantly different for males and females. The difference between the mid-dates for males and females increases by approximately 2 days with each year of age. Figures 3 to 6 illustrate these differences between sexes.

The oldest female fur seal alive is perhaps 25-30 years of age. From the first series of tagging experiments in 1941, four 20-year-old females were recovered in 1961. A female identified by tooth-layer counts as 26 years old was killed at sea in 1959. If the trend of dates of mid-molt is projected to the female of age 26, the date of 17 February is reached, a date which is compatible with finding of one old female in beginning molt on 5 January 1961.

The mid-date of molt for the average 6-year male is 27-28 September, the same as for the yearling female. This means that all males age 5 and younger tend to pass through mid-molt before females of any age. Since the

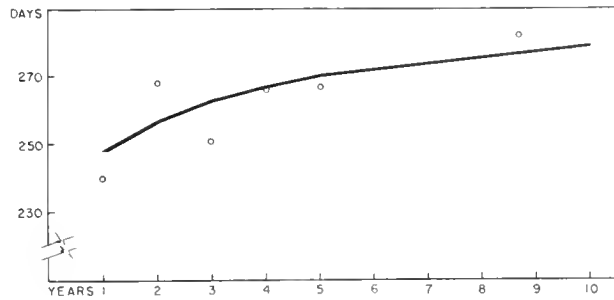

Figure 5.--Molt mid-dates; logarithmic curve fitted to data from table 6; male. (Y = 248.41 + 30.27 log X.)

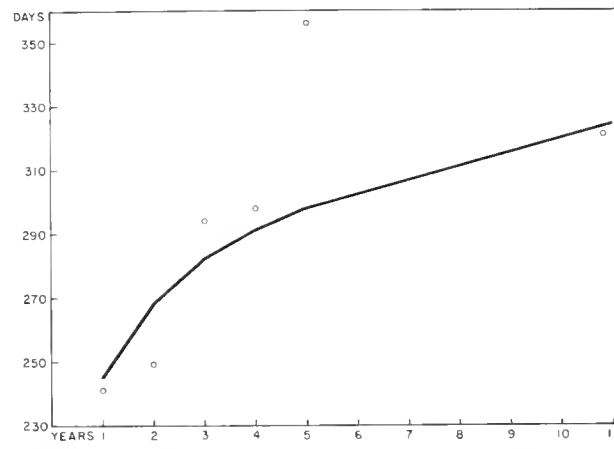

Figure 6.--Molt mid-dates; logarithmic curve fitted to data from table 6; female. (Y = 245.40 + 75.65 log X.)

Table 6.--Molt mid-dates of the northern fur seal smoothed from the data of table 5 by linear and logarithmic regression equations[1]

Age	Both sexes		Male		Female		Difference between sexes	
	Linear	Logarithmic	Linear	Logarithmic	Linear	Logarithmic	Linear	Limits
Years							*Days*	*Days*
1	[2]271(±2)	255	254(±2)	248	270(±7)	245	16	7-25
2	275(±2)	271	257(±2)	257	275(±6)	268	18	10-26
3	278(±2)	280	261(±2)	263	280(±5)	282	19	12-26
4	282(±2)	286	264(±1)	267	286(±5)	291	22	16-28
5	285(±2)	291	268(±2)	270	291(±4)	298	23	17-29
10	303(±3)	306	285(±4)	279	317(±6)	320	32	22-42

[1] In the body of the table are given mid-dates expressed as the number of days from the first of January. The relationship between a seal's age and the mid-date of its molt is expressed, alternatively, as linear or logarithmic.

[2] Here, for example, the 95 percent confidence limits are 269 to 273.

body weight of the 6-year male is four times that of the yearling female, and since members of the two classes molt at the same time, it may be concluded that season of molt is dependent more upon sex than upon body size.

Females molt later and arrive later on the breeding grounds than do males of the same age. For example, when tagged yearlings were searched for in the period mid-September to mid-November on St. Paul Island, 18 males to 5 females were found in 1941 and 12 males to 6 females in 1961. A causal relationship between late molt and late arrival should not be inferred.

Older seals molt later in autumn; they also may (?) exhibit greater variation in time of molt. Table 7 shows a significant increase in length of the overall molting period with increase in age of seal ($P < 1$ percent). The molting season for 15 yearlings extends over a period of 106 days (3.5 months), and for 58 seals older than 10 years over a period of 171 days (5.6 months). As previously mentioned (page 9), the findings could mean that in older seals, either molt is more erratic or slower, or both.

PERSISTENCE OF OLD-GENERATION GUARD HAIRS AFTER THE MOLT

Evidence from Inspection of the Guard Hair Shafts

From inspection of the pelage fibers in early spring it is apparent that at least two generations (year classes) of guard hairs are present. The older hairs are dull and faded, with tips frayed or broken and with shafts pock-marked or eroded at the edges. The newer hairs are dark brown, with long, slender, glistening, transparent tips and with smooth shafts. The hairs start to deteriorate in March, when a few are slightly faded and their tips are brushy. By May, all show fading, though a few still have sharp tips. By July, all hairs are faded and all tips are moderately to excessively frayed. It is now impossible to distinguish the old from the new generation.

On the basis of 225 specimens representing female seals older than 1 year, killed between January and June, estimates of the percentage composition of guard hairs as old or new have been made. The estimates are based on larger hairs only--the ones which compose the outer ranks and which can be counted. Smaller hairs are protected by the pelage and some of them remain sharp and unfaded for a year or more. The estimates are unsatisfactory for the following reasons: First, they fluctuate widely from one sample to the next, even when the samples represent animals of the same class and season of year. For example, in 13 3-year-olds taken in February 1961, the estimates are (percent old fibers): 5, 10, 15, 15, 25, 35, 35, 40, 50, 60, 60, 70, and 80. The wide range is believed to represent, for the most part, poor judgment in identifying old and new hairs. Second, the estimates show no clear relationship to age of seal or to month of collection.

When the data for all samples are combined, however, they suggest that, on the average, about 25 percent of the larger guard hairs of the female between January and June are unshed hairs of the previous generation. An analysis by month for 225 specimens is given below:

	Jan.	Feb.	Mar.	Apr.	May	June	Total
Mean percent old hairs	29.4	28.3	22.2	20.1	27.2	5.7	24.4
Number in sample	42	57	55	47	16	8	225

Evidence from Inspection of the Guard Hair Roots

While the new guard hair fiber is pushing its way upward through the skin and through the old pelage, its course for about a month runs parallel to the resident fiber. The two fibers share a common pilary funnel (skin pore). During active stages of molt, the stumps of many such paired fibers or "twins" show on a horizontal section cut near the surface of the skin (table 8).

In beginning molt, by definition, the hairs have not yet erupted. Only about 1 percent of the pilosebaceous units near the surface of the skin contain twin hairs. In early and late molt,

Table 7.--Increase in length of overall molting period with increase in age of the northern fur seal[1]

Age	Sex	Seals in sample[2]	Dates between which seals in molt were taken		Length of molting period	
			Beginning	Ending	Total	Mean
Years		*Number*			*Days*	*Days*
1	M	12	21 June	9 Oct.	110	106
	F	3	21 July	7 Oct.	88	
		15				
2	M	47	21 June	13 Nov.	145	127
	F	21	17 Aug.	13 Nov.	88	
		68				
3	M	35	22 June	15 Nov.	146	140
	F	30	29 June	8 Nov.	132	
		65				
4	M	16	18 July	14 Oct.	888	135
	F	31	29 June	5 Dec.	159	
		47				
5	M	9	5 Sep.	12 Oct.	37	138
	F	29	4 July	13 Nov.	169	
		38				
6-10[3]	M	8	23 July	15 Nov.	115	97
	F	17	17 Aug.	13 Nov.	88	
		25				
> 10[4]	M	10	5 Aug.	15 Nov.	102	171
	F	48	10 Aug.	23 Jan.	166	
		58				

[1] For each age and sex class there is shown the total period during which some seals were in molt.

[2] Total 316 seals, including seals not in molt but taken during the molting period for the year class.

[3] Mean age of males 6.4 years; of females 7.4; of both 7.1.

[4] Mean age of males 11.0 years; of females 12.3; of both 12.1.

from 2 to 73 percent (mean 28.5) of the units contain twin hairs. In ending molt, the percentage drops to less than 2; over 98 percent of the units contain a single hair. No satisfactory way of identifying the mature hair stump at this stage as either new or old generation has been found. In the resting stage which follows molt and extends for 8 or 9 months, no twin hair stumps can be seen. In other words, as a new hair develops fully, the old one is shed.

The data in table 8 show not only variation in percentage of twin hairs with stage of molt, but also with age of seal. They suggest an

Table 8.--Age, molting stage, and pilosebaceous units with twin guard hairs[1] among northern fur seals

Age	Beginning molt			Early molt			Late molt			Ending molt			Total
	Seals	Pilosebaceous units with twin guard in hairs		Seals	Pilosebaceous units with twin guard in hairs		Seals	Pilosebaceous units with twin guard in hairs		Seals	Pilosebaceous units with twin guard in hairs		
		Range	Mean		Range	Mean		Range	Mean		Range	Mean	
Years	*Number*	%	%	*Number*	%	%	*Number*	%	%	*Number*	%	%	
1	2	0-0	0	1	--	29	1	--	15	2	1-5	3	6
2	3	0-6	2	3	15-28	20	4	0-48	20	--	--	--	10
3	3	0-0	0	4	13-25	19	2	2-33	17	--	--	--	9
4	3	0-0	0	2	27-42	35	1	--	66	1	--	0	7
5	2	0-12	6	3	18-63	37	1	--	44	--	--	--	6
>5	6	0-1	1	3	24-73	41	1	--	38	2	0-1	1	12
Total	19			16			10			5			50
Mean percent			1.0			29.1			27.6			1.6	

[1] Percent units containing a new as well as an old hair stump (viewed on a horizontal section of skin near the surface). Sexes combined, 50 specimens.

increase in percentage in older seals. Thus, the combined percentages for early and late molt are:

Age	Sample	Mean percent pilosebaceous units with twin guard hairs
Years	*Number*	
1	2	22.0
2	7	19.6
3	6	18.7
4	3	45.0
5	4	41.0
>5	4	40.0

To test whether the diameter of the hair stump is a clue to its age, the transverse (= greatest) width of 507 stumps was measured. (Measurements were made on photoenlargements at 100X.) The sample represents 10 adult, nonmolting females collected between January and early October. The results are shown in table 9. Stump width varies widely and for no apparent reason. Width frequencies tend to be bimodally distributed. See, for example, those for a 5-year-old in July (table 9). This observation parallels another, namely, that guard hair shafts are mainly of two sizes, larger and smaller, with few intermediates.

Table 9.--Width of guard hair roots in adult, nonmolting fur seal females[1] by month of collection and by age of seal in years

Width	Width frequencies										
	Jan.		Mar.	Apr.	May	June	July		Sept.	Oct.	Total
	age 15	age 5	age 17	age 11	age 11	age 12	age 5	age 13	age 12	age 11	
Microns											
45	--	--	--	--	1	--	5	--	--	--	6
50	--	3	--	2	2	--	10	--	--	1	18
55	--	6	--	8	4	--	11	--	1	1	31
60	--	9	1	12	13	1	6	--	4	3	49
65	--	9	1	9	8	6	2	2	7	4	48
70	2	2	--	7	8	9	5	6	6	3	48
75	4	7	5	8	4	5	3	3	7	10	56
80	4	9	2	8	6	7	8	5	5	5	59
85	4	7	4	4	7	4	7	8	2	2	49
90	5	7	2	4	2	5	7	8	5	8	53
95	3	4	3	--	2	1	1	9	2	9	34
100	4	--	7	--	3	4	--	2	2	6	28
105	4	2	2	--	--	2	--	2	2	-	14
110	4	3	1	--	--	--	--	1	--	--	9
115	3	-	1	--	--	--	--	1	--	--	5
Mean width, microns	93	75	90	69	71	80	67	86	77	82	77.4
No. of roots in sample	37	68	29	62	60	44	65	47	43	52	507

[1] Transverse (greatest) width of each root stump near surface of skin; measured from tissue sectioned horizontally in paraffin, stained and mounted.

Interpretation of the Evidence

The presence of old-generation guard hairs in the fresh, resting pelage might be interpreted in two ways. Either (a) each old hair is an unshed "holdover" twinned with and emerging from the same pore as a younger companion, or (b) each old hair is standing alone in a follicle which was inactive in the last molt. Since in subsurface sections of resting skin twin hair stumps are not present, each old hair must in fact represent an inactive follicle.

The percentage of old hair shafts is roughly 25, and the maximum percentage of twin hair stumps, each of which represents the renewal of a hair, is 73. If a maximum of about 75 percent twin hair stumps is attained in an individual when, temporarily, all of the old hairs are present with all of the new ones, then, for mature seals at least, about 75 percent of the resting guard hairs would be new generation and 25 percent would be old.

Is the ratio of new to old hairs, or annual rate of replacement, similar for seals of all ages? Twin hair stumps are less abundant in seals of ages 1, 2, and 3 than in older seals. The increase with age could mean that shedding is more prolonged in old seals and prompter in young ones, or it could mean that the annual replacement of hairs in old seals is more complete--more extensive. The evidence available does not answer this question.

Incomplete molt of the guard hair was demonstrated in the course of marking experiments carried on by R. S. Peterson in the summer of 1961. He marked a number of bulls by clipping (shearing) or by chemically bleaching patches of hair. In letter of 3 June 1962 he wrote that "the clipped areas have grown out but the new guard hairs are a . . . lighter shade than the old; while the bleached hairs are still retained, though less prominent than before." His observations may be interpreted as follows: On clipped areas all of the hairs seen in 1962 were new ones with unbroken white tips, and they were only three-fourths as abundant as hairs in the surrounding unmarked pelage. On bleached areas, three-fourths of the hairs seen in 1962 were presumably new, undamaged ones, and one-fourth were unshed bleached hairs of the old generation.

Danforth (1939, p. 109) found that human hairs "show a remarkable degree of autonomy, which is maintained over long periods and is not readily disturbed by external factors. Each follicle has its own individual rhythm . . . ."

PERSISTENCE OF OLD-GENERATION UNDERFUR FIBERS AFTER THE MOLT

Whereas old guard hairs are distinguishable from new by the amount of fading and wear of the shaft, the same test cannot be applied to underfur fibers. These are buried in the pelage and do not become faded or worn. Underfur roots provide the only evidence.

The Number of Underfur Fibers per Bundle

The number of underfur fibers per bundle was counted in 20 bundles for each of 120 seals. The results are given in table 10; selected data are given below:

Minimum count for any bundle (a 1-year female in January and a 1-year male in February)	9
Minimum mean count for any seal (a 1-year male in February)	14.0
Maximum count for any bundle (an old male in September in early molt)	89
Maximum mean count for any male	67.7
Maximum mean count for any female	50.8
Mean count for all seals	39.2

Variation in Number of Fur Fibers with Age and Sex

In both sexes, in the first adult-type pelage, the underfur fiber count per bundle is 14 to 24 (mean 17.9). These figures are based on 15 of the 21 silver pups and yearlings represented in table 10, to the exclusion of 6 yearlings which are in, or have passed through their

Table 10.--Number of fur seal underfur fibers per bundle by age, sex, and month[1]

Age	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	N	Mean
Years							*Male*							
0	--	--	--	--	--	--	--	--	16	16	17	--	4	16.3
1	--	14	19	21	--	22	17	--	27	31	--	--	8	22.2
2	25	27	26	23	23	26	25	28	30	28	33	--	11	26.7
3	33	39	29	32	26	32	33	29	31	36	43	--	11	33.0
4	31	--	--	29	--	33	40	32	31	39	42	--	9	34.2
5	--	--	--	--	37	--	31	--	38	44	--	--	4	37.5
>5	--	--	--	46	42	41	48	47	62	38	59	--	10	48.6
N	3	3	3	5	4	6	6	4	11	7	5	--	57	
Mean	29.7	26.7	24.7	30.2	32.0	32.5	32.3	34.0	33.7	33.1	38.8	--	--	32.35
							Female							
0	--	--	--	--	--	--	--	--	17	19	24	--	3	20.0
1	16	--	20	19	18	--	22	--	--	21	--	--	6	19.3
2	28	--	27	25	--	--	--	28	36	31	31	--	7	29.4
3	33	27	32	30	34	28	32	33	30	34	46	--	11	32.6
4	32	27	37	27	37	35	34	34	33	37	--	37	11	33.6
5	34	33	38	35	--	40	29	38	37	51	36	--	10	37.1
>5	35	41	43	43	37	40	35	36	43	45	36	42	15	39.8
N	6	4	7	6	4	4	5	6	6	7	5	3	63	
Mean	29.7	32.0	34.3	29.8	31.5	35.7	30.4	34.1	32.7	34.0	34.6	40.3	--	33.00

[1] From counts on paraffin mounts, horizontal, representing 120 specimens. Age "0" represents a silver pup. An underlined figure represents the mean of two specimens. Mean age for >5 males is 10.0 years; for >5 females, 12.3 years. See also table 11.

second molt. In both sexes the count rises steadily, more sharply at first, during the adolescent and subadult years. In the full-grown male the maximum count is 68 per bundle; in the full-grown female, 51.

Quadratic equations fit the data of table 10 more closely (table 11 and figure 7) than do linear equations. From figure 8 it will be seen that the regression curves of fiber count on age are similar for both sexes up to age 5. After age 5 they diverge slightly. The number of fibers per bundle continues to increase until 12 years of age in the male and 10 years in the female. Quadratic equations cannot be used to extrapolate to older age classes. If the sample had included more old animals, an exponential curve would perhaps have provided a better fit for data throughout the entire life span of the seal.

It is important to note that the fiber counts of table 10 are arranged by age of seal and not by age of pelage. The two are slightly different. For example, a "1-year-old" by definition is a seal in the period 1 January to 31 December of its second calendar year, partly in its first pelage and partly in its second. The quadratic

Table 11.--Number of fur seal underfur fibers per bundle by age and sex[1]

Age	Pelage	Fibers	
		Male	Female
Years		*Number*	*Number*
0	1st	14.8	14.9
1	1st + 2d[2]	20.5	20.5
2	2d + 3d	25.8	25.5
3	3d + 4th	30.6	30.0
4	4th + 5th	34.9	33.8
5	5th + 6th	38.8	37.1
8	8th + 9th	47.4	43.5
10	10th + 11th	50.8	44.9
12	12th + 13th	52.8	--

[1] Estimates by curve fitting, based on the weighted means (right-hand column) of table 10.

[2] For example, a "1-year-old" by definition is a seal in the period 1 January to 31 December of its second calendar year, partly in its first pelage and partly in its second.

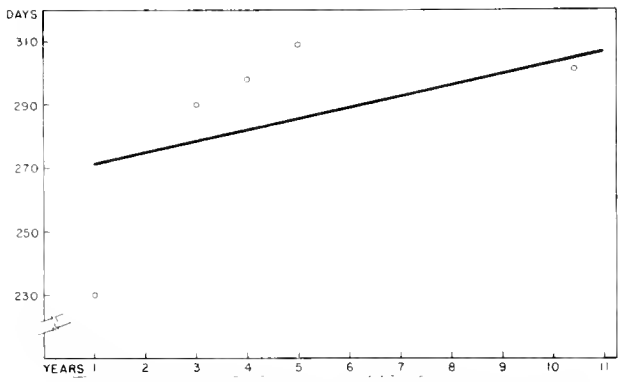

Figure 7.--Molt mid dates; straight line fitted to data from table 6; sexes combined. (Y = 267.53 + 3.59X.)

models are based on calendar age of the seal and should be interpreted accordingly. They are mainly useful in showing that fiber populations increase at the same rate in males and females through age 5, and that the populations level off earlier in females than in males. The counts give a better understanding of the fiber populations in youngest and oldest animals than do the models.

Variation in Number of Fur Fibers with Season

The counts which are summed up in the bottom rows of table 10 contain data from

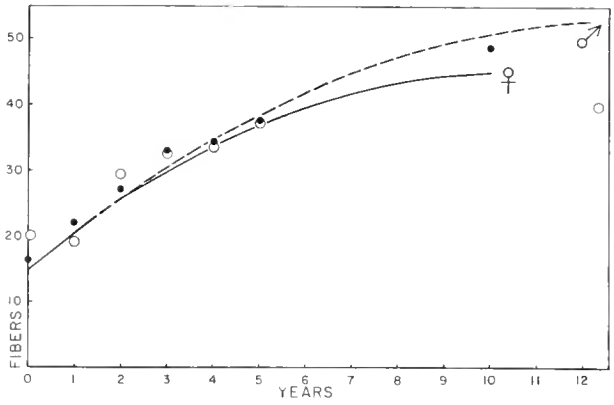

Figure 8.--Number of underfur fibers per bundle, by age and sex: quadratic curves fitted to the data of table 11. (Male, ($Y = 14.76 + 5.99\ X - 0.236\ X^2$; female, $Y = 14.89 + 5.90\ X - 0.290\ X^2$).

many age classes. To look for fiber count changes correlated with season, it is necessary to follow the trend of one age class, or a few similar age classes. Where the sampling was good, for example, of 2- and 3-year males, and 3-, 4-, 5-, and > 5-year females, the data by age indicate that the fiber count remains unchanged during winter, spring, and summer when the pelage is resting. The fibers are held fast in the bundle. As might be expected, the count rises during molt in autumn, when new hairs are erupting faster than old ones are being shed. It subsequently declines to the resting level.

The Number of Active Underfur Roots per Bundle

The counts of underfur fibers were taken near the surface of the skin. Deeper in the skin of an actively molting seal, however, the fiber count is lower. For example, in an 11-year male in early molt, the mean surface count is 56.0 (47 to 61), while the count just below the level of the sweat glands is only 19.8 (15 to 27). Furthermore, at deeper levels there are only well-formed follicular bulbs, while at shallower levels there are shafts of these bulbs and also shafts without bulbs.

Interpretation of the Evidence

It has been shown (a) that the underfur fiber population per bundle rises, with increasing age of the seal, from about 18 to about 51 in the female and 68 in the male and (b) that during active molt the population of follicles with bulbs in the deeper dermis is about the same, regardless of age of seal, as it was in the original pelage.

The deduction is made that the seal has, at a time no later than its first autumn, and more likely in utero, all of the underfur germs it is ever to have. As the surface area of the skin increases, the fur bundles become less crowded, and increasing numbers of fibers remain in place, unshed, after each new crop has erupted. When growth of the surface area ceases, the fur fiber count levels off.

The phenomenon of fiber retention beyond the molt may be summarized as follows: In the guard hair layer, fibers more than a year old represent individual follicles which skipped the last molt. In the underfur layer, fibers more than a year old represent follicles which were pushed aside by the last erupting crop and which have not yet shed their fibers. Here the fur bundle holds all of the fibers, new and old, that it can. In the mature seal in resting stage, the percentages of new and old fur fibers are about 25:75 for the male and 33:67 for the female. (These percentages are calculated from counts, table 10. The percentages calculated from smoothed counts, table 11, would be 28:72 and 33:67, respectively.)

It is reasonable to suppose that "reluctant shedding," or the persistence of old-generation guard hairs and underfur fibers, has survival value to the seal. It helps to maintain a heat-insulating coat throughout the molting season.

This interpretation agrees with the findings of Margolena (1954, p. 765). She started with the premise that "once a tissue is differentiated it is usually incapable of producing new organs" and found that, in Karakul sheep, all follicles are established in fetal life and their population remains constant.

It has not been determined what fraction, if any, of the underfur follicle population remains inactive during molt. Nor has it been determined what fraction, if any, of the fiber population remains in place for longer than 2 years.

CHANGES IN DEPTH OF THE PELAGE

Measurements of the depth of the guard hair and underfur layers on tanned sealskins were reported by Scheffer (1962, p. 72).

Table 12.--Slant depth of the furseal underfur by age, sex, and month (millimeters)[1]

Age	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Years							*Male*						
0[2]	--	--	--	--	--	--	--	--	11.3	11.7	12.0	--	11.7
1	--	12.0	12.0	12.0	--	11.0	13.0	--	11.7	13.3	12.0	--	12.2
2	11.0	12.0	12.3	12.4	14.0	12.4	12.3	11.7	12.1	12.7	12.2	--	12.3
3	12.0	12.0	12.5	12.1	13.0	12.3	12.1	12.3	12.4	12.5	12.0	--	12.2
4	12.0	--	--	11.2	--	12.3	12.7	12.0	12.3	12.2	13.0	--	12.1
5	--	--	--	--	--	12.5	13.0	--	12.2	12.0	--	--	12.3
>5	--	--	--	13.0	13.5	13.4	12.5	13.3	13.1	12.7	13.0	--	13.1
Mean	11.7	12.0	12.3	12.0	13.5	12.6	12.4	12.3	12.2	12.5	12.2	--	12.3
							Female						
0[2]	--	--	--	--	--	--	--	--	12.0	12.2	12.5	--	12.3
1	11.5	--	11.9	12.0	13.5	--	11.0	--	--	12.5	--	--	12.1
2	11.7	--	12.0	11.7	15.0	--	--	12.0	12.3	11.5	12.3	--	12.1
3	11.7	11.9	11.6	12.0	13.0	12.0	12.7	12.0	11.8	11.8	11.7	--	11.9
4	12.0	12.1	11.6	12.1	12.0	12.3	11.8	12.0	12.0	11.6	12.0	12.0	12.0
5	11.3	11.4	12.0	12.0	--	12.0	11.3	11.6	11.6	11.7	12.0	--	11.6
>5	11.3	11.1	11.1	11.8	11.9	11.6	11.8	11.6	11.7	12.0	12.0	11.5	11.5
Mean	11.5	11.6	11.5	11.9	12.3	11.8	11.7	11.8	11.8	11.9	12.0	11.7	11.7

[1] Mean values from measurements of 222 male and 447 female specimens; total 669.
[2] Silver pups.

The results of measuring the depth of underfur on 669 new samples are given in table 12. The depth varies little with age, sex, or month. Whether silver pups, middle-aged individuals, or old ones, the depth is about 11.5 to 12.5 mm. The mean for all males is 12.3 mm., for all females 11.7; a difference of only 5 percent. Maximum depth in males is 16 mm., in females 14 mm.

From study of table 12 two conclusions may be drawn. First, depth of underfur tends to decline slightly with age. This probably results from the spreading apart of the fur bundles as the body surface increases. With more space around them, the fibers assume a more wavy attitude and, as a group, give the effect of a shallower layer. Second, the tendency to effect a shallower layer with age is, in the male, completely masked by the rival tendency for fibers to grow in length at age 5 and beyond, in the years of sexual maturing. A spurt in growth of guard hair length, especially in the mane, is easily seen at this time. Probably the fur fibers also increase in length.

CHANGES IN COLOR OF THE PELAGE

The Change from Black to Silver in the Pup

At birth the pup is wearing its fetal black coat. Already, however, the adult-type coat is beginning to form, deep in the dermis. In September the pup coat changes from black to silver. In 28 specimens taken between 1 September and 11 October (mean date 19 September), molt is in the following stages:

Pups recorded in life as "black"	
Number in early molt	9
Number in late molt	6
Pups recorded in life as "silver"	
Number in late molt	7
Number in ending molt	3
Number resting in postmolt	3

Thus it is evident that during late molt, when the new guard hair tips have grown to or beyond the underfur layer, the birthcoat hairs that give a black appearance to the pelage are rapidly being shed. The age of the individual when the change takes place is not known, though it is certainly near 3 months. Two pups of known age, 50 and 63 days respectively, would still be called "black" (R.S. Peterson, in letter, 1961).

Change in Color of the Underfur With Age, Sex, and Season

No differences in color of underfur attributable to sex or season were detected in 48 dry slices of pelage representing six age groups, two sexes, and two seasons (spring and fall), when all slices were displayed together on a black table. With age there is a gradual shift toward a darker and redder color.

On the silver pup and yearling, the Munsell colors are between "pale yellowish pink" and "light grayish brown" (7.5 YR 8/2 and 6/2). The fur is silvery to grayish with only a faint suggestion of brown. Along the outer (distal) one-third of its length the fur has a slightly more brownish appearance; a result of pigment granules in the fiber cortex. Magnified, the granules are seen as short rods 1 micron or less in length, arranged parallel to the axis of the fiber.

On the 2-year-old, the color tends to be distinctly darker and browner; between "light grayish brown" and "light brown" (7.5 YR 6/2 and 6/4). An occasional light 2-year-old is like a dark yearling. Between 2- and 3-year-olds, the eye can detect a faint break. Between 3's and 4's, and between 4's and 5's, the break is imperceptible. In the group older than 5 years, however, most specimens are darker than the subadults. Maximum color is seen in an old male specimen: "moderate brown" (5YR 3/3); a rich cocoa brown.

Where the pelage fibers emerge from the skin pore, and for a distance of about 1 mm. beyond, they are brownish, as though stained. The color is pale or absent in pelagic (first coat) yearlings, and darker--up to chestnut--in full-grown seals. Since the color does not extend into the roots and since it appears concurrently with the maturation of the sweat glands, it is probably produced by the secretions of the sweat glands at their point of exit.

Appearance of White Guard Hairs in the Male

The presence of scattered large, white guard hairs is a secondary sex character in the adult male. White hairs may be seen in some 3- and 4-year-olds, and in about one-half of the 5-year-olds. One October 5-year-old shows 7 new white guard hairs per linear cm. on a transverse section. In old bulls, white hairs may compose

up to one-third of the longer hairs of the back. Thus the fifth year is the one in which the body pelage of the male tends to become grizzled; it is also the one in which pigment formation in the vibrissae roots is ending (Scheffer, 1962, p. 73).

All-white hairs may be seen occasionally in seals other than old males. In one 17-year female, about 10 percent of the shorter hairs are white.

CHANGES IN THE DERMIS

Change in Depth of the Dermis

The slant depth of the dermis was measured on 570 dried specimens (table 13). For comparative purposes, slant depth may serve as "depth of skin."

Mean depth of dermis for males is 5.3 mm.; for females 5.1 mm. Maximum depth in the male, 14 mm., is noted on a 9-year-old. Maximum depth in the female, 8 mm., is noted on four individuals, and 11-year-old and three recorded as "age 10+."

The depth of dermis of males and females was found to increase with age (b = 0.6 mm. and 0.2 mm. for males and females, respectively ($P < .01$ for each)). The estimated increase for females, 0.2 mm. per year, is probably somewhat low for ages 0 through 5 and probably high for older individuals. That is, a linear regression line was fitted to data which probably are not linear, but because of the few age groups (six) curvilinear methods would do little to improve the estimate. The estimated increase of 0.6 mm. per year for males seems to be better, since the dermis continues to increase at a fairly constant rate until age 10 (?) years or beyond. The dermis of molting animals is thicker than that of nonmolting animals ($P < .01$).

Change in the Sweat Gland and Adjacent Fat Cells

Whereas hair follicles and sebaceous glands are derivatives of the embryonic epidermis, the sweat gland at the base of each pilosebaceous unit is a derivative of the dermis. It starts to develop deep in the skin and does not become functional for at least 4 months after birth--probably much later. Its history is sketched below:

1. Newborn pup in beginning molt. The unformed sweat gland is a series of short tubes, seen in cross section as circles, one-cell thick.

2. Silver pup in late molt. The first ducts are visible at the surface; an appropriate section may show two sebaceous ducts and a sweat duct paralleling the hair shaft.

3. Silver pup in postmolt resting stage. Sweat glands are entire, though small. The connective tissue sheath shows its characteristic spiral arrangement.

4. Late autumn yearling, after the second molt. The gland is full size or nearly so. At this time a few glands may show dilations or reservoirs characteristic of the adult.

The fat cells which, in the adult, lie in grape-like clusters beneath and among the deeper coils of the sweat gland, first appear in the pelagic yearling. They start to form in spring, at a maximum depth of only 2 mm., and do not become conspicuous until the second year of life. In old seals during molt they reach a depth of 55 mm. The skin of the yearling is more elastic than the skin of the adult. Perhaps the scarcity of dermal fat cells is partly responsible.

In addition to histological evidence, there are gross clues which point to more fat in the skin in the older animal. Fifty-five envelopes containing dry pelage samples from females of various ages, collected in February 1961, were held at room temperature for 1 month. Oil stains showed on the outside of the envelopes, as follows: age 3, only 1 in 14 stained; ages 4 and 5, 22 nearly unstained; age 6, 3 in 3 stained; and ages 7 and older, 12 in 16 stained. Workers handling finished seal skins have remarked at the presence of a faint, dark "oily" stain which extends along the mid-dorsal line of the leather side of old female skins, but is not seen on skins of younger animals.

It has long been known that the blubber layer tends to increase in thickness as the seal

Table 13.--Slant depth of the fur seal dermis by age, sex, and molt (frequency distribution)

Depth of dermis	Age in years							Total
	0[1]	1	2	3	4	5	>5[2]	
Mm.				*Male, nonmolting*				
2.5	-	1	-	-	-	-	-	1
3.0	-	3	-	-	-	-	-	3
3.5	-	4	5	2	-	-	-	11
4.0	-	-	8	6	4	-	-	18
4.5	-	-	4	10	4	-	-	18
5.0	-	-	2	5	7	2	-	16
5.5	-	-	-	1	-	3	-	4
6.0	-	-	-	-	1	1	2	4
6.5	-	-	-	-	-	-	2	2
7.0	-	-	-	-	-	-	-	-
7.5	-	-	-	-	-	-	1	1
8.0	-	-	-	-	-	-	1	1
8.5	-	-	-	-	-	-	1	1
9.0	-	-	-	-	-	-	-	-
9.5	-	-	-	-	-	-	-	-
10.0	-	-	-	-	-	-	4	4
10.5	-	-	-	-	-	-	-	-
11.0	-	-	-	-	-	-	2	2
11.5	-	-	-	-	-	-	-	-
12.0	-	-	-	-	-	-	-	-
12.5	-	-	-	-	-	-	-	-
13.0	-	-	-	-	-	-	1	1
13.5	-	-	-	-	-	-	-	-
14.0	-	-	-	-	-	-	1	1
Total	-	8	19	24	16	6	15	88

[1] Black pups and silver pups combined
[2] Mean age of 15 nonmolting old males 8.47 years.

Depth of dermis	Age in years							Total
	0[1]	1	2	3	4	5	>5[2]	
Mm.				*Male, molting*				
2.5	-	1	-	-	-	-	-	1
3.0	2	-	-	-	-	-	-	2
3.5	1	-	-	-	-	-	-	1
4.0	8	3	9	4	1	-	-	25
4.5	-	2	6	6	1	-	-	15
5.0	-	2	7	6	2	-	-	17
5.5	-	-	3	5	1	-	-	9
6.0	-	1	2	2	6	2	-	13

Table 13.--Slant depth of the fur seal dermis by age, sex, and molt (frequency distribution).--Continued

Depth of dermis	Age in years							Total
	0[1]	1	2	3	4	5	>5[2]	
Mm.				*Male, molting--Continued*				
6.5	-	-	1	-	-	-	1	2
7.0	-	-	-	-	2	3	-	5
7.5	-	-	-	-	-	1	-	1
8.0	-	-	-	-	-	1	2	3
8.5	-	-	-	-	-	-	-	-
9.0	-	-	-	-	-	-	2	2
9.5	-	-	-	-	-	-	2	2
10.0	-	-	-	-	-	-	1	1
10.5	-	-	-	-	-	-	-	-
11.0	-	-	-	-	-	-	-	-
11.5	-	-	-	-	-	-	-	-
12.0	-	-	-	-	-	-	1	1
12.5	-	-	-	-	-	-	-	-
13.0	-	-	-	-	-	-	1	1
13.5	-	-	-	-	-	-	-	-
14.0	-	-	-	-	-	-	1	1
Total	11	9	28	23	13	7	11	102

[1] Black pups and silver pups combined.
[2] Mean age of 11 molting old males 10.18 years.

Depth of dermis	Age in years							Total
	0[1]	1	2	3	4	5	>5[2]	
Mm.				*Female, nonmolting*				
3.0	-	7	-	-	-	-	-	7
3.5	-	3	2	3	-	-	-	8
4.0	-	3	6	22	11	3	5	50
4.5	-	1	2	13	12	9	12	49
5.0	-	-	2	9	16	11	34	72
5.5	-	-	1	-	5	5	20	31
6.0	-	-	-	-	-	2	30	32
6.5	-	-	-	-	-	-	13	13
7.0	-	-	-	-	-	-	15	15
7.5	-	-	-	-	-	-	4	4
Total	-	14	13	47	44	30	133	281

Table 13.--Slant depth of the fur seal dermis by age, sex, and molt (frequency distribution).--Continued

Depth of dermis	Age in years							Total
	0[1]	1	2	3	4	5	>5[2]	
Mm.				*Female, molting*				
2.5	1	-	-	-	-	-	-	1
3.0	-	-	-	-	-	-	-	-
3.5	2	1	-	-	-	-	-	3
4.0	6	-	1	1	-	-	-	8
4.5	-	-	4	6	10	2	-	22
5.0	1	1	3	6	6	4	5	26
5.5	-	-	1	1	1	3	-	6
6.0	-	-	-	5	1	3	9	18
6.5	-	-	-	1	-	1	3	5
7.0	-	-	-	-	-	-	5	5
7.5	-	-	-	-	-	-	1	1
8.0	-	-	-	-	-	-	4	4
Total	10	2	9	20	18	13	27	99

[1] Black pups and silver pups combined.
[2] Mean age of 133 nonmolting old females 11.38 years; of 27 molting old females 11.15 years.

grows to adulthood. While the blubber is distinct from the layer of dermal fat cells, the metabolism of the two fat depots is presumably linked, and changes in one layer are reflected in the other.

Change in the Sebaceous Gland

The cross-section width of a large sebaceous gland on each of 52 cross-section mounts representing 52 seals (table 14) ranged from 75 to 350 microns with a mean of 198 microns. The two largest measurements (307 and 350 microns) are from a 12-year female in August and a 15 year female in January, both in beginning molt. Although there is some indication of an increase in the width of the gland with age and molt, the data are highly variable and are insufficient for some year classes to show the exact relationship.

Change in Weight

The weight data are from a small but fairly homogenous group: 429 females, not obviously pregnant, older than 10 years. The results are given in table 15 and figure 9. They suggest an increase from about 32 kg. in January to 44 kg. in June, during a period when seals are pelagic. A sharp dip in April, observed in the data both for 1958 and 1959, is unexplained. A June sample taken at sea has, perhaps by chance, the same mean weight as an overlapping sample taken on land. After June, the weight drops slightly. It fluctuates between 39 and 42 kg. until November. While no sample was taken in December, the trend is quite surely downward during this month.

The mid-date of molt for older-than-10-year females is late November or early December (by extrapolation from table 6). This is the time when body weight is declining, but it is also the time when seals are subjected to cold, stormy weather at sea. The relative importance of the two factors, molting and weather, cannot be evaluated from the data at hand and therefore the relationship of molt to weight fluctuation is not clear.

COMPARISON OF PELAGE, MALE AND FEMALE, BACK AND BELLY

The adult female pelt tends to be scarred, presumably from the bites of other seals. And

Table 14.--Width of the furseal sebaceous gland by age, sex, month, and molt (millimeters)[1]

Age	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Years						*Male*							
1	--	75	--	--	--	--	--	--	185	--	--	--	130
2	--	--	--	--	--	--	--	160	--	--	--	--	160
3	220	--	--	--	--	150	140	--	205	200	--	--	183
4	200	--	--	100	--	--	220	--	210	215	--	--	189
Mean	210	75	--	100	--	150	180	160	201	208	--	--	175
						Female							
1	--	--	150	--	--	--	140	--	--	--	--	--	145
2	150	--	--	--	--	--	--	160	170	--	--	--	160
3	190	--	--	--	--	155	205	185	155	185	--	--	179
4	235	--	245	210	--	135	185	225	155	250	--	200	204
5	--	--	--	210	--	280	150	175	250	255	--	--	220
>5[2]	350	200	260	185	230	215	150	258	245	240	--	225	234
Mean	231	200	218	202	230	196	166	210	195	233	--	216	206

[1] From measurements of 13 males and 39 females. Underlined values represent seals in molt.
[2] The figure for August is the mean of 210 and 307; the figure for December is the mean of 245 and 205.

Table 15.--Change in body weight of the northern fur seal female by month[1]

	Jan.	Feb.	Mar.	Apr.	May	June
Mean weight kilograms	32.4	37.8	38.8	34.3	39.9	43.6
Number in sample	7	68	63	35	34	12
Source of data	([2])	([2])	([2])	([2])	([2])	([2])

	June	July	Aug.	Sept.	Oct.	Nov.
Mean weight kilograms	43.7	40.3	38.9	41.7	40.5	40.5
Number in sample	49	57	46	7	23	28
Source of data	([3])	([3])	([3])	([3])	([4])	([4])

[1] Based on 429 mature animals, age 11 years or older, not pregnant (or if pregnant, with embryo of microscopic size).
[2] Seals taken at sea (Wilke, Niggol, and Fiscus, 1958, p. 46 and 96; Niggol, Fiscus, and Wilke, 1959, p. 33 and 85); mean age 14.9 years.
[3] Seals taken on land (data from field cards for Pribilof Islands, 1953).
[4] Seals taken on land (data from field cards for Pribilof Islands, 1961).

the adult female pelt tends to lose fur, especially from the belly, during the unhairing process in the finishing factory. Aside from scarring, the factors which depreciate the adult female pelt are virtually unknown. Some are perhaps chemical or physiological as, for example, varying concentrations and kinds of oils in the dermis. Others are perhaps technological, related to the fact that only since 1956 have processors been faced with the new problem of finishing adult female pelts by the thousands. Still other factors might be related to differences in fiber size and distribution, or thickness of skin. In a search for such differences, skin samples from the back and belly of 21 seals were examined (see technique

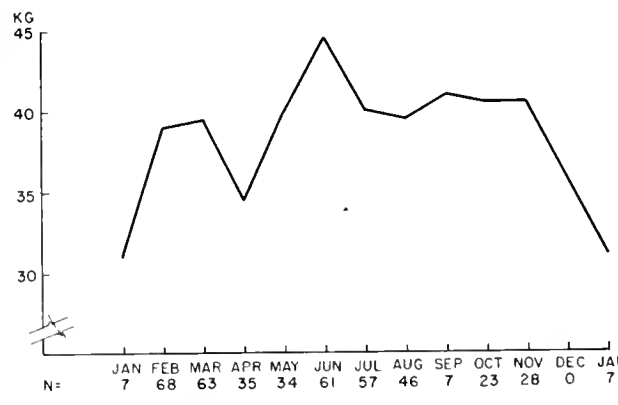

Figure 9.--Change in body weight of the female by month, based on 429 mature animals, age 11 years or older, not pregnant.

of collection, p. 4). The sample includes 9 males taken in July to November 1961 and 12 females taken in July to October 1961 (table 16).

Effect of Age

The counts of fur bundles per cm^2 on the back are, for the

3-year male (N = 3)	1,296
4-year male (N = 6)	1,096
5-year female	1,108
6-year female	1,073
7-year female	981
8-year female	1,098
9-year female	965
12-year female	930
"Adult" female, estimated age 12 years	928
15-year female	790

The number of fur bundles per $cm.^2$ decreases with increasing age of seal ($P < .01$). The rate of change is -33.2 per year. The linear equation, $Y = 1{,}168 - 33.2X$ represents the relationship of the number of fur bundles per $cm.^2$ with age. It is evident that, as long as the seal continues to grow in size and surface area, the average distance between pilosebaceous units increases.

From the foregoing table, the mean number of fur bundles per $cm.^2$ for two 12-year females is 929. Multiplying by 45, the estimated number of fur fibers per bundle (table 11), the product is 41,805 fur fibers per $cm.^2$, or 269,642 per $inch^2$. The latter figure is believed to be a more precise estimate than an earlier one, 370,000 per $inch^2$, given by Scheffer (1962, p. 7).

Effect of Sex.

With respect to pelage fibers and thickness of skin, the subadult male and the adult female of comparable size are similar (table 16). The male fibers tend to be slightly longer and more

Table 16.--Comparison of pelage, male and female of the northern fur seal, back and belly[1]

	Mean values	
	Male	Female
Age, years	3.6	8.7
Length, cm	116.0(4)	120.0(7)
Weight, kg	27.0(4)	30.6(5)
Slant depth of dermis on back, mm	5.1	5.1
Slant depth of dermis on belly, mm	5.1	5.1
Depth of guard hair on back mm	19.1	18.6
Depth of guard hair on belly, mm	12.8	12.0
Depth of underfur on back, mm	11.7	11.9
Depth of underfur on belly, mm	7.6	6.7
Number of underfur bundles per $cm.^2$ on back	1162.7	1012.0
Number of underfur bundles per $cm.^2$ on belly	1188.2	1066.0
Number of underfur fibers per bundle on back	31.6(2)	44.9(3)
Number of underfur fibers per bundle on belly	--	41.2(2)

[1] On 9 male and 12 female seals from which equal-area squares of skin were removed. Where a mean value is based on fewer than 9 males or 12 females, N is shown in parentheses.

closely spaced than the female fibers, though the differences would be unimportant to a furrier. The underfur fiber population of the male is 11-15 percent denser than that of the female.

The effect of sex within age cannot be estimated because the sampling program was designed to provide, not seals of comparable age but of comparable size.

Effect of Location, Back or Belly

The density of underfur fibers on the back may be regarded as equal to that on the belly. In the sample of 21 seals, the density on the back exceeds that on the belly for 10 animals, and vice versa for 11. Over all, the density on the belly exceeds that on the back by 3.9 percent.

The underfur fibers per bundle were counted in paraffin mounts representing back and belly pelage of two 8-year females in nonmolting condition. The counts were, respectively: back 44.0, belly 43.4; back 46.4, belly 38.9.

SUMMARY

A square of skin was taken from the back of each of 321 fur seals in molt. From gross and histological examination, four stages of molt were identified and described. These are: beginning (duration about 2 weeks), early (6 weeks), late (4 weeks), and ending (3 weeks); total 15 weeks. Molt of the underfur precedes that of the guard hair by about 1 week. Duration of molt in the fur seal is similar to that in *Mustela vison* (13 weeks) and *Vulpes fulva* (14.5 weeks).

The observed molting period was from 21 June to 23 January of the following year (216 days or 7.1 months); the probable extremes are mid-June to mid-March, or 9 months. The mid-date of molt is reached when growing guard hair tips are nearing the outer surface of the underfur layer. The mid-date is later in older seals; it is slightly earlier in males than in females. (Males also return to the breeding islands earlier in summer than do females of the same age.) The estimated mid-date of molt for males is 3.4 days later with each year of increasing age; for females 5.5 days. The sex discrepancy widens by approximately 2 days with each year of age. For example, the mid-dates of molt for extreme groups are: 1-year males, 11 September; females, 26 September; difference 16 days. Ten-year males, 12 October; females, 13 November; difference 32 days. Season of molt is dependent more upon sex than upon body size. Yearlings pass through molt at various times within a period of 3.5 months; older-than-10-year seals within a period of 5.6 months; the difference may be (?) a sampling effect.

In the female, at least, about 25 percent of the longer guard hairs are old-generation fibers representing follicles which have skipped a molt.

The number of underfur follicles per bundle in the first adult-type pelage is 14 to 24 (mean 17.9). It remains unchanged throughout life. However, the number of fibers increases with age, to 51 in the full-grown female and 68 in the full-grown male. The rise in fiber count means that up to 60 percent of the fibers are not shed in late molt but remain fast in the bundle. The fiber count increases at the same rate through age 5 in both sexes.

The persistence of old generation (the preceding year's) guard hairs and underfur fibers helps to maintain a heat-insulating coat on the seal throughout the molting season.

Depth of underfur is consistently near 11.5 to 12.5 mm., reaching a maximum of 16 mm. in old males.

Coat color of the pup changes most rapidly from black to silver at about age 3 months, in mid-October.

The underfur of the adult-type pelage is silvery to pale grayish brown in the yearling. It is distinctly darker and browner in the 2-year-old. With each increasing year of life up to about 10 years, the underfur darkens almost imperceptibly. In one old male the color is rich cocoa brown.

In the male, the coat becomes grizzled in about the fifth year, following the eruption of

long, colorless guard hairs which may compose up to one-third of the longer hairs on the back.

Mean slant depth (or depth in the plane of the hair roots) of the dried dermis is 3.8 to 4.0 mm. in silver pups. In the male it increases with age to 8.9 mm., in the female to 5.8 mm. The thickness increases significantly with age and with molt.

The sweat gland does not reach full size until the seal has entered its second year. From morphological evidence, the gland is probably functional by the time the seal, as an autumn yearling, returns to land. Fat cells clustered around the base of the gland follow a similar schedule to maturation. They descend, with increasing age of the seal, from a slant depth of 2 mm. to a depth of 5 mm. Old females, at least, have an oilier skin than young females.

Sebaceous glands are functional at birth. They may (?) increase in size with age and with molt, though the sample is too small to prove or disprove it.

In a selected sample of old females, body weight increases during spring, when the seals are feeding at sea. From June to November it drops slightly and, though data are lacking, it evidently drops sharply in December. The decline coincides with the mid-date of molt in old females.

The fiber-bundle count per cm.^{2} decreases with age of seal (and increased area of body surface). The count for a 3-year male is 1,296 bundles per cm.^{2}; for a 15-year female, 790. In seals of similar size, subadult males and adult females, the fiber-bundle count is similar for both sexes and for back as compared with belly. In the back pelage of the 12-year female there are estimated to be 929 guard hairs and 41,805 fur fibers per cm.^{2}, or 275,634 total fibers per inch.^{2}

ACKNOWLEDGMENTS

The senior author is responsible for histological observations; the junior author for statistical treatment of the findings. Ian B. McAskie and Gordon C. Pike, both of the Fisheries Research Board of Canada, collected some of the study samples. Douglas G. Chapman, of the University of Washington, advised on statistical methods.

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